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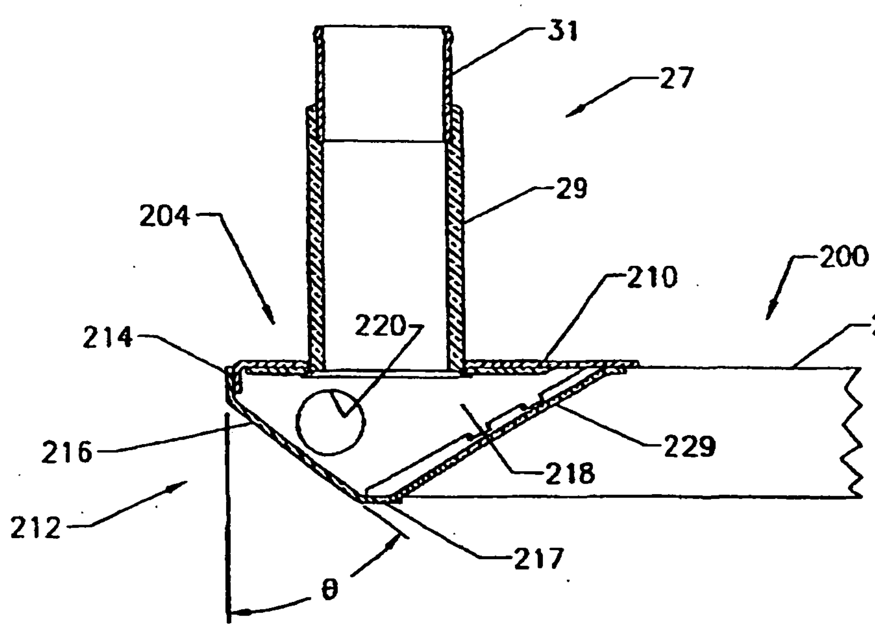
(54) Title: HEAT EXCHANGER WITH BEVELED HEADER



(57) Abstract: A header for a heat exchanger, the header having a beveled closed end portion.

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HEAT EXCHANGER WITH BEVELED HEADER

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to heat exchangers, and more particularly to heat exchangers for cooling engines, generators, gear boxes and other heat generating sources in industrial apparatuses having fluid cooled heat sources, such as marine vessels. The invention more particularly relates to open heat exchangers (where heat transfer tubes are exposed to the ambient cooling or heating fluid, rather than being in a shell to shell container holding the cooling or heating fluid) used for cooling heat sources, where the heat exchangers are efficient, and thus have lower weight and volume compared to other heat exchangers known in the art. Alternatively, the heat exchanger according to the invention could be used as a heater, wherein relatively cool fluid absorbs heat through the heat transfer tubes.

Description of the Prior Art

Heat generating sources in industrial applications such as marine vessels are often cooled by water, other fluids or water mixed with other fluids. For example, in marine vessels used in fresh water and/or salt water, the cooling fluid or coolant flows through the engine or other heat generating source where the coolant picks up heat, and then flows to another part of the plumbing circuit. The heat must be transferred from the coolant to the ambient surroundings, such as the body of water in which the vessel is located. For small engines, such as outboard motors for small boats, ambient water pumped through the engine is a sufficient coolant. However, as the vessel power demand gets larger, ambient water pumped through the engine may continue to provide good cooling of the engine, but also serves as a source of significant contamination damage to the engine. If raw, ambient water were used to cool the engine, the ambient water would carry debris and, particularly if it is salt water, corrosive chemicals to the engine. Therefore, there have been developed various apparatuses for cooling engines and other heat sources. One apparatus for cooling the engine of a vessel is channel steel, which is basically a large quantity of shaped steel which is welded to the bottom of the hull of a vessel for conveying engine coolant and transferring heat from the coolant to the ambient water. Channel steel has severe

limitations: it is very inefficient, requiring a large amount of steel in order to obtain the required cooling effect; it is very expensive to attach to a vessel, since it must be welded to the hull - a very labor intensive operation; since channel steel is very heavy, the engine must be large enough to carry the channel steel, rendering both the initial equipment costs and the operating costs very high; the larger, more powerful engines of today are required to carry added channel steel for their cooling capacity with only a relatively small amount of room on the hull to carry it; the payload capacity is decreased; the large amount of channel steel is expensive; and finally, channel steel is inadequate for the present and future demands for cooling modern day, marine vessels. Even though channel steel is the most widely used heat exchanger for vessels, segments of the marine industry are abandoning channel steel and using smaller keel coolers for new construction to overcome the limitations cited earlier.

A keel cooler was developed in the 1940's and is described in U.S. Patent No. 2,382,218 (Fernstrum). The Fernstrum patent describes a heat exchanger for attachment to a marine hull structure which is composed of a pair of spaced headers secured to the hull, and a plurality of heat conduction tubes, each of whose cross-section is rectangular, which extend between the headers. Cylindrical plumbing through the hull connects the headers to coolant flow lines extending from the engine or other heat source. Hot coolant leaves the engine, and runs into a heat exchanger header located beneath the water level (the water level refers to the water level preferably below the aerated water, i.e. below the level where foam and bubbles occur), either beneath the hull or on at least one of the lower sides of the hull. The coolant then flows through the rectangular heat conduction tubes and goes to the opposite header, from which the cooled coolant returns to the engine. The headers and the heat conduction tubes are disposed in the ambient water, and heat transferred from the coolant, travels through the walls of the heat conduction tubes and the headers, and into the ambient water. The rectangular tubes connecting the two headers are spaced fairly close to each other, to create a large heat flow surface area, while maintaining a relatively compact size and shape. Frequently, these keel coolers are disposed in recesses on the bottom of the hull of a vessel, and sometimes are mounted on the side of the vessel, but in all cases below the water line.

The foregoing keel cooler is referred to as a one-piece keel cooler, since it is an integral unit with its major components welded or brazed in place. The one-piece keel cooler is generally installed and removed in its entirety.

There are various varieties of one-piece keel coolers. Sometimes the keel cooler is a multiple-pass keel cooler where the headers and heat conduction tubes are arranged to allow at least one 180° change in the direction of flow, and the inlet and outlet ports may be located in the same header.

Even though the foregoing heat exchangers with the rectangular heat conduction tubes have enjoyed wide-spread use since their introduction over fifty years ago, they have shortcomings which are corrected by the present invention.

The rectangular heat exchangers of the prior art have the outward shape of a rectangular parallelepiped having headers at their opposite ends. These headers have opposing end walls which are perpendicular to the hull of the vessel and parallel to each other, and act as a barrier to ambient water flow relative to the keel cooler as the vessel with the heat exchanger travels through the water. The perpendicular header walls are responsible for the creation of dead spots (lack of ambient water flow) on the heat exchanger surfaces, which largely reduce the amount of heat transfer occurring at the dead spots. In addition, the perpendicular walls diminish the flow of ambient water between the heat conduction tubes, which reduces or diminishes the amount of heat which can be transferred between the coolant in the tubes and the ambient water.

As discussed below, the beveled header, contributes to the increase of the overall heat transfer efficiency of the keel cooler according to the invention, since the ambient water is caused to flow towards and between the respective heat conduction tubes, rendering the heat transfer substantially higher than in the keel cooler presently being used. This increase in heat transfer is due at least in part to the increase in turbulence in the flow of ambient water across the forward header and along and between the coolant flow tubes.

One of the important aspects of keel coolers for vessels is the requirement that they take up as small an area on the vessel as possible, while fulfilling or exceeding their heat exchange requirement with minimized pressure drops in coolant flow. The area on the vessel hull which is used to accommodate a keel cooler is referred to in the

art as the footprint. In general, keel coolers with the smallest footprint and least internal pressure drops are desirable. One of the reasons that the keel cooler described above with the rectangular heat conduction tubes has become so popular, is because of the small footprint it requires when compared with other keel coolers. However, keel coolers according to the design of rectangular tubed keel coolers presently being used have been found by the present inventors to be larger than necessary both in terms of size and the related internal pressure drop. By the incorporation of the various aspects of the present invention described above (and in further detail below), keel coolers having smaller footprints and lower internal pressure drops are possible. These are major advantages of the present invention.

When multiple pass (usually two pass) keel coolers are specified for the present state of the art, an even greater differential size is required when compared with the present invention, as described below.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a heat exchanger for fluid cooled heat sources which is smaller than corresponding heat exchangers having the same heat exchange capability.

Another object of the present invention is to provide an improved heat exchanger for industrial applications which is more efficient than heat exchangers presently known and used.

It is yet another object of the present invention to provide an improved one-piece heat exchanger for vessels which is more efficient in heat transfer than presently known one-piece heat exchangers.

A further object is to provide an improved one-piece heat exchanger which reduces the pressure drop of coolant flowing therethrough.

A further object of the present invention is to provide an improved one-piece heat exchanger having heat conduction tubes which are rectangular in cross-section having a length which is reduced in size from the current heat exchangers due to enhanced ambient water flow across the keel cooler.

Another object is to provide an improved one-piece heat exchanger having a reduced size from present one-piece heat exchangers of comparable heat transfer

capability, by reducing the length of the heat transfer tubes, the number of tubes and/or the size of the tubes.

A still further object of the present invention is to provide a new one-piece heat exchanger having rectangular shaped heat conduction tubes which has enhanced durability compared to keel coolers presently on the market.

A related object of the invention is to provide an improved heat exchanger and headers thereof which is capable of deflecting debris more readily, and for presenting a smaller target to debris in the ambient water.

Another object of the present invention is to provide an improved one-piece keel cooler which is easier to install on vessels than corresponding keel coolers presently on the market.

Yet a further object of the present invention is to provide a one-piece heat exchanger and a header having a lower weight, and therefore lower cost, than corresponding one-piece heat exchangers presently in use.

Another object of the present invention is to provide a one-piece heat exchanger and headers thereof having rectangular heat conduction tubes having a lower pressure drop in coolant flowing through the heat exchanger than corresponding heat exchangers presently known.

Another object of the present invention is the provision of a one-piece heat exchanger for a vessel, for use as a retrofit for previously installed one-piece heat exchangers which will surpass the overall heat transfer performance and provide lower pressure drops than the prior units without requiring additional plumbing, or requiring additional space requirements, to accommodate a greater heat output.

It is another object of the invention to provide an improved header for a one-piece heat exchanger having rectangular coolant flow tubes.

Another object is to provide an improved header for a one-piece heat exchanger with rectangular coolant flow tubes which reduces the dead spots which have heretofore reduced the heat transfer capabilities of one-piece heat exchangers, the dead spots reducing the flow of ambient water around and between the coolant flow tubes.

A further object of the invention is to provide an improved header for a one-

piece keel cooler with rectangular coolant flow tubes, by reducing the likelihood of damage to the header from striking debris and underwater objects which could damage the keel cooler.

It is still another object for the provision of a header for effecting increased turbulent flow of the ambient water flowing between and around the heat transfer tubes.

It is an additional object to provide an improved header for one-piece keel coolers which enables the anode for such keel coolers to be less likely to strike debris and underwater objects.

Another object is the provision of a keel cooler having a smaller, and more streamlined profile to reduce drag as the vessel with the keel cooler moves through the ambient water.

Another object is to provide a header for a one-piece heat exchanger which provides for enhanced heat exchange between the coolant and the ambient cooling medium such as water.

A general object of the present invention is to provide a one-piece heat exchanger and headers thereof which is efficient and effective in manufacture and use.

Other objects will become apparent from the description to follow and from the appended claims.

The invention to which this application is directed is a one-piece heat exchanger, i.e. heat exchangers having two headers which are integral with coolant flow tubes. It is particularly applicable to heat exchangers used on marine vessels as discussed earlier, which in that context are also called keel coolers. However, heat exchangers according to the present invention can also be used for cooling heat generating sources (or heating cool or cold fluid) in other situations such as industrial and scientific equipment, and therefore the term heat exchangers covers the broader description of the product discussed herein. The heat exchanger includes two headers, and one or more coolant flow tubes integral with the header. Although keel coolers use ambient water as the cooling medium, the broader term for a cooling medium is a heat sink or a fluid heat sink.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a schematic view of a heat exchanger on a vessel in the water.

FIGURE 2 is a side view of an engine for a vessel having a one-piece keel cooler according to the prior art installed on the vessel and connected to the engine;

FIGURE 3 is a pictorial view of a keel cooler according to the prior art;

FIGURE 4 is a partial pictorial view of a partially cut-away header and a portion of the coolant flow tubes of a one-piece keel cooler according to the prior art;

FIGURE 5 is a cross-sectional view of a portion of a keel cooler according to the prior art, showing a header and part of the coolant flow tubes;

FIGURE 6 is a side, cross-sectional, partial view of a portion of one-piece keel cooler according to the invention, showing a header and part of the coolant flow tubes;

FIGURE 7 is a pictorial view of a portion of a one-piece keel cooler according to the invention, with portions cut away;

FIGURE 8 is a pictorial view of a header and part of the coolant flow tubes of a one-piece keel cooler according to the invention;

FIGURE 9 is a side view of part of the apparatus shown in FIGURE 8;

FIGURE 10 is a front view of the apparatus shown in FIGURE 8;

FIGURE 11 is a partial bottom view of the apparatus shown in FIGURE 8;

FIGURE 12 is a side view of a portion of a header according to the invention showing the flow lines of ambient water; and

FIGURE 13 is a pictorial view of a keel cooler according to the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The fundamental components of a heat exchanger system for a water going vessel are shown in FIGURE 1. The system includes a heat source 1, a heat exchanger 3, a pipe 5 for conveying the hot coolant from heat source 1 to heat exchanger 3, and a pipe 7 for conveying cooled coolant from heat exchanger 3 to heat source 1. Heat source 1 could be an engine, a generator or other heat source for the vessel. Heat exchanger 3 could be a one-piece keel cooler (since only one-piece keel coolers are discussed herein, they are generally only referred to herein as "keel coolers.") Heat exchanger 3 is located in the ambient water, below the water line (i.e. below the aerated water line), and heat from the hot coolant is transferred through the walls of

heat exchanger 3 and expelled into the cooler ambient water.

FIGURE 2 shows a heat exchanger 11 mounted on a vessel, for transferring heat from the coolant flowing from an engine or other heat source 13 to the ambient water. Coolant flows from one of lines 14 or 15 from engine 13 to keel cooler 11, and back through the other flow pipe from keel cooler 11 to engine 13. Keel cooler 11 is attached to, but spaced from the hull of vessel.

A keel cooler 17 according to the prior are is shown in FIGURE 3. It includes a pair of headers 19, 21 at opposite ends of a set of parallel, rectangular coolant flow tubes 23, having interior tubes 25 and two exterior tubes (discussed below). A pair of nozzles 27, 28 conduct coolant into and out of keel cooler 17. Nozzles 27, 28 have cylindrical threaded connectors 29, 30, and nipples 31, 32 at the ends of the nozzles. Headers 19, 21 have a generally prismatic construction, and their ends 34, 35 are perpendicular to the parallel planes in which the upper and lower surfaces of tubes 23 are located. Keel cooler 17 is connected to the hull of a vessel through which nozzles 27 and 28 extend. Large gaskets 36, 37 each have one side against headers 19, 21 respectively, and the other side engages the hull of the vessel. Rubber washers 38, 39 are disposed on the inside of the hull when keel cooler 17 is installed on a vessel, and metal washers 40, 41 sit on rubber washers 38, 39. Nuts 42, 43, which typically are made from metal compatible with the nozzle, screw down on sets of threads 44, 45 on connectors 29, 30 to tighten the gaskets and rubber washers against the hull to hold keel cooler 17 in place and seal the hull penetrations from leaks

Turning to FIGURE 4, a partial, cross section of the current keel cooler according to the prior art and depicted in FIGURE 3, is shown. Keel cooler 17 is composed of the set of parallel heat conduction or coolant flow tubes 23 and the header or manifold 19. Nozzle 27 is connected to header 19 as described below. Nozzle 27 has nipple 31, and connector 29 has threads 44 as described above, as well as washer 40 and nut 42. Nipple 31 of nozzle 27 is normally brazed or welded inside of a connector 29 which extends inside the hull. Header 19 has an upper wall or roof 47, outer back wall 34, and a bottom wall or floor 48. Header 19 includes a series of fingers 52 which are inclined with respect to tubes 23, and define spaces to receive ends 55 of interior tubes 25.

Referring also to FIGURE 5, which shows keel cooler 17 and header 19 in cross section, header 19 further includes an inclined surface 49 composed of fingers 52. End portions 55 of interior tubes 25 extend through surface 49. Interior tubes 25 are brazed or welded to fingers 52 to form a continuous surface. A flange 56 surrounds an inside orifice 57 through which nozzle 27 extends and is provided for helping support nozzle 27 in a perpendicular position on the header 19. Flange 56 engages a reinforcement plate 58 on the underside of wall 47.

In the discussion above and to follow, the terms "upper", "inner", "downward", "end" etc. refer to the heat exchanger, keel cooler or header as viewed in a horizontal position as shown in FIGURE 5. This is done realizing that these units, such as when used on water going vessels, can be mounted on the side of the vessel, or inclined on the fore or aft end of the hull, or various other positions.

Each exterior side wall of header 19 is comprised of an exterior or outer rectangular tube, one of which is indicated by numeral 60 in FIGURE 4. The outer tubes extend into header 19. FIGURES 4 and 5 show both sides of outside tube wall 61. Both sides of interior wall 65 are shown in FIGURE 4 and 5. A circular orifice 69 is shown extending through interior wall 65 of the outside rectangular tube of keel cooler 17, and is provided for carrying coolant flowing through the outside tube into or out of header 19. In this regard, nozzle 27 can either be an inlet conduit for receiving hot coolant from the engine whose flow is indicated by the arrow A in FIGURE 5, or be an outlet conduit for receiving cooled coolant from header 19 for circulation back to the heat source.

FIGURE 4 also shows that keel cooler header 19 has a drainage orifice 71 for receiving a correspondingly threaded and removable plug. The contents of keel cooler 17 can be removed through orifice 71.

Still referring to the prior art header 19 shown in FIGURES 3 - 5, it can be seen that outer back wall 34 and floor 48 are formed at right angles. This configuration has led to a number of disadvantages, previously unrecognized by those designing and working on keel coolers. First, by having wall 34 perpendicular to the direction of flow of the coolant through the tubes, greater pressure drops occur inside of header 19 as the coolant becomes chaotically turbulent and is forced through the coolant flow

tubes at varying flow rates depending on resistance. This leads to a net reduction in flow and thus of heat transferred from the coolant through tubes 23 of keel cooler 17. With respect to the outside of wall 34, the vertical wall acts as an obstruction to the flow of ambient water, and diminishes the amount of ambient water which is able to flow between and around tubes 23. In addition, vertical wall 34 serves as an obstruction to debris in the ambient water and absorbs the full impact of the debris leading to potential damage to the keel cooler. Moreover, having wall 34 and floor 48 defining a right angle increases the amount of material used for keel cooler 17, which adds to its expense. Most keel coolers are made from 90-10 copper-nickel (or some other material having a large amount of copper), which is a relatively expensive material. In addition, significant drag is created by the resistance which the vertical wall presents to ambient water. This restricts the flow of ambient water to the heat exchange tubes of the keel cooler, and adds to the drag of the vessel as it moves through the water.

Still referring to FIGURES 3 - 5, gaskets 36, 37 are provided for three essential purposes: (1) they insulate the header to prevent galvanic corrosion, (2) they eliminate infiltration of ambient water into the vessel, and (3) they permit heat transfer in the space between the keel cooler tubes and the vessel by creating a distance of separation between the heat exchanger and the vessel hull, allowing ambient water to flow through that space. Gaskets 36, 37 are generally made from a polymeric substance. In typical situations, gaskets 36, 37 are between one quarter inch and three quarter inches thick. Keel cooler 17 is installed on a vessel as explained above. The plumbing from the vessel is attached by means of hoses to nipple 31 and connector 29 and to nipple 32 and connector 30. A cofferdam or sea chest (part of the vessel) at each end (not shown) contains both the portion of the nozzle 27 and nut 42 directly inside the hull. Sea chests are provided to prevent the flow of ambient water into the vessel should the keel cooler be severely damaged or torn away, where ambient water would otherwise flow with little restriction into the vessel at the penetration location.

Referring next to FIGURES 6 - 11, the invention in the preferred embodiment is shown. The embodiment includes a keel cooler 200 with coolant flow tubes (or heat transfer fluid flow tubes, since in some instances the fluid may be heated instead of

cooled) 202 having a generally rectangular cross section. A header 204 is an integral part of keel cooler 200. Tubes 202 include interior or inner coolant flow tubes 206 and outermost or exterior tubes 208. A nozzle 27 having nipple 31 and threaded connector 29, are the same as those described earlier and are attached to the header. Header 204 includes an upper wall or roof 210, a beveled closed end portion 212 having an end wall 214 transverse to (and preferably perpendicular to) upper wall 210 and a beveled, bottom wall 216 beginning at end wall 214 and terminating at a generally flat lower wall 217. Beveled wall 216 should be greater in length (from end wall 214 to lower wall 217) than the height of end wall 214. An interior wall 218 (FIGURES 6-7) of exterior or outermost rectangular flow tube 208 has an orifice 220 (one per header for each tube 208) which is provided as a coolant flow port for coolant flowing between the chamber of header 204 and outer flow tubes 208 (The chamber is defined by upper wall 210, an inclined surface or inner end or inlet end portion 229, beveled bottom wall 216, lower wall 217 and end wall 214). Header 204 also has an anode assembly (not shown) for reducing corrosion of the keel cooler.

Considering specifically cut away FIGURE 7, keel cooler 200 includes rectangular tubes 202 with interior tubes 206 and outermost tubes 208, and inner wall 218 (with orifice 220) of the outermost tubes. The open ends or inlets or ports for interior tubes 206 are shown by numerals 227. Tubes 206 join header 204 through inclined surface 229 (FIGURE 6) on the opposite part of header 204 from beveled wall 216. Exterior tubes 208 have outer walls 230, part of which are also the side walls of header 204. A gasket 232, similar to and for the same purpose as gasket 36, is disposed on roof 210.

The angle of beveled wall 216 is an important part of the present invention. As discussed herein, the angle, designated as θ (theta), is appropriately measured from the plane perpendicular to the longitudinal direction of coolant flow tubes 202 and located at the part of the closed end portion of header 204 spaced furthest from the set of open ends or ports 227 of tubes 206, i.e. from end wall 214, to beveled wall 216. Angle θ is described as an exterior angle, since it is exterior to end wall 214 and beveled bottom wall 216; it is measured from a plane perpendicular to the longitudinal axes of the flow tubes 202 and roof 210, and it is along end wall 214 at the beginning of beveled

bottom wall 216. The factors for determining angle θ are to maintain the center to center distance of the nozzle spacing, to maintain the overall length of the keel cooler, to provide vertical drop beneath the roof of the header so that the header can hold the anode insert, to keep the anode assembly from extending longitudinally beyond wall 214, and to allow for the maximum length of heat transfer tubing (and the associated reduction of the length of the header). Angle θ could be affected by the size of orifice 220, but generally the other factors limit angle θ before the orifice would affect it.

Another important aspect to beveled wall 216 is the manner in which it directs the flow of ambient water over and between the exterior walls of coolant flow tubes 202, to increase the heat transfer between the coolant inside the tubes and the outside ambient water. It will be recalled that under the prior art as shown in FIGURES 3 - 5, vertical wall 34 diverted the ambient water as the vessel passed therethrough, so that the ambient water to a significant extent went around rather than between and over the separated rectangular tubes 27.

Referring to FIGURE 12, which shows a side view of keel cooler 200, arrows B show the flow pattern of ambient water across keel cooler 200 as the keel cooler moves to the right through the ambient water. Arrows B show that the water impinges on beveled wall 216, flows around the beveled wall, and, due to the drop in pressure, along inclined surface 229 and up and between coolant flow tubes 202. This flow is turbulent which greatly increases the transfer of heat from the heat conduction tubes as compared to the prior art shown in FIGURES 3 - 5, yielding a more efficient and effective heat exchanger than those of the prior art.

Keel coolers according to the invention are used as they have been in the prior art, and incorporate two headers which are connected by an array of parallel coolant flow tubes. A common keel cooler according to the invention is shown in FIGURE 13, which illustrates a keel cooler 200' having opposing headers 204 like the one shown in FIGURE 7. The headers shown have the identical numbers to those shown in FIGURE 7. Heated coolant fluid flows into one nozzle 27 from a heat source in the vessel, then flows through one header 204, the coolant flow tubes 202, the other header 204, the other nozzle 27, and the cooled coolant flows back to the heat source in the vessel. While flowing through headers 204 and coolant flow tubes 202, the

coolant transfers heat to the ambient water. All of the advantages of the beveled wall 216 apply to keel cooler 200'.

The keel coolers described above show nozzles for transferring heat transfer fluid into or out of the headers. However, there are other means for transferring fluid into or out of the headers; for example, in flange mounted keel coolers, there are one or more conduits such as pipes extending from the hull and from the keel cooler having end flanges for connection together to establish a heat transfer fluid flow path. Normally a gasket is interposed between the flanges. There may be other means for connecting the keel cooler to the coolant plumbing system in the vessel. This invention is independent of the type of connection used to join the keel cooler to the coolant plumbing system.

The invention has been described with particular reference to the preferred embodiments thereof, but it should be understood that variations and modifications within the spirit and scope of the invention may occur to those skilled in the art to which the invention pertains.

What is claimed is:

1. A one-piece heat exchanger comprising:

a plurality of coolant flow tubes extending in a longitudinal direction for carrying coolant fluid from a heat source for transferring heat from the coolant fluid cooling medium and for returning the cooled coolant fluid back to the heat source, said coolant flow tubes having a set of inner tubes and exterior side tubes, said inner tubes having at least one set of open ends proximate each other;

a header connected to said coolant flow tubes at said set of open ends of said tubes, said header having an inlet end portion for receiving coolant from and/or delivering coolant to said coolant flow tubes through said open ends, a closed end portion opposite said inlet end portion transverse to the longitudinal direction of said coolant flow tubes, said closed end portion having a beveled wall beveled from an end plane perpendicular at the beginning of the bevel to the longitudinal direction of said coolant flow tubes towards said inlet end portion.

2. A heat exchanger according to claim 1 wherein the amount of bevel of said beveled wall is at an exterior angle θ (theta) measured from said end plane to said beveled wall, said angle θ being between 0° and 90°.

3. A heat exchanger according to claim 2 wherein said rectangular coolant flow tubes have external side heights of 2 ½ inches, and external side widths of ½ inches.

4. A heat exchanger according to claim 3 wherein said angle θ is 52°

5. A heat exchanger according to claim 1 wherein said header has a flat upper surface perpendicular to said plane, and said closed end portion includes an end wall extending from said flat upper surface and being in said end plane, and said beveled wall extends from said end wall at an exterior angle θ from said end wall, said angle θ being between 0° and 90°.

6. A heat exchanger according to claim 5 wherein said beveled wall has a length greater than the height of said end wall.

7. The invention according to claim 5 wherein the height of said end wall is no greater than 1.125 inches.

8. A header for a heat exchanger for cooling a heat source, the heat exchanger having a plurality of inner coolant flow tubes extending in a longitudinal direction for

carrying coolant flow from a heat source for transferring heat from the coolant fluid to a fluid heat sink, the coolant flow tubes being generally rectangular in cross section, and disposed in a generally parallel relationship, the inner coolant flow tubes having at least one set of open ends in proximity to each other, said header comprising:

an inlet end portion for receiving coolant from and/or delivering coolant to the open ends of the inner coolant flow tubes; and

a closed end portion opposite said inlet end portion, said closed end portion being transverse to the longitudinal direction towards the coolant flow tubes; the closed end portion having a beveled wall beveled from an end plane perpendicular to the longitudinal direction of the coolant flow tubes and located at a part of said closed end portion spaced furthest from the set of open ends of the coolant flow tubes, in the direction towards the coolant flow tubes.

9. A header according to claim 8 and further comprising an upper surface generally parallel to the longitudinal direction, and an end wall extending from and perpendicular to said upper surface, said beveled portion extending from said end wall towards the coolant flow tubes.

10. A header according to claim 9 wherein said beveled wall is beveled at an exterior angle θ (theta) measured from said end wall to said beveled wall, said angle θ being between 0° and 90°.

11. A header according to claim 10 wherein said angle θ is 52°.

12. A header according to claim 9 wherein said beveled wall has a length greater than the height of said end wall.

13. A header according to claim 9 wherein the height of said end wall is no greater than 1.125 inches.

14. A one-piece keel cooler for water vessels, said keel cooler comprising:

a plurality of inner coolant flow tubes extending in a longitudinal direction for carrying coolant fluid from a heat source for transferring heat from the coolant fluid to ambient water, said inner coolant flow tubes being generally rectangular in cross section and disposed in a generally parallel relationship, said inner coolant flow tubes having at least one set of open ends proximate each other;

a header connected to said inner coolant flow tubes at said set of open ends of said inner coolant flow tubes, said header having an inlet end portion for receiving coolant from and/or delivering coolant to inner said coolant flow tubes through said open ends, a closed end portion opposite said inlet end portion transverse to the longitudinal direction of said coolant flow tubes, said closed end portion having a beveled wall beveled from an end plane perpendicular to the longitudinal direction of said coolant flow tubes and located at the part of said closed end portion of said header spaced furthest from said set of open ends of said coolant flow tubes, in the direction towards said coolant flow tubes.

15. A keel cooler according to claim 14 wherein the amount of bevel of said beveled wall is at an exterior angle θ measured from said end plane to said beveled wall, said angle θ being less than 90°.

16. A keel cooler according to claim 15 wherein said rectangular coolant flow tubes have external side heights of 2 ½ inches, and widths between the respective sides of ½ inches.

17. A keel cooler according to claim 16 wherein said angle θ is 52°.

18. A keel cooler according to claim 14 wherein said header has a flat upper surface perpendicular to said end plane, and said closed end portion includes a vertical wall extending from said flat upper surface and being in said end plane, and said beveled wall extends from said vertical wall at an exterior angle θ from said wall, said angle θ being between 0° and 90°.

19. A keel cooler according to claim 18 wherein said beveled wall has a surface length greater than the height of said vertical wall.

20. The invention according to claim 18 wherein the height of said vertical wall is no greater than 1.125 inches.

21. A header for a keel cooler for a water vessel, the keel cooler having a plurality of inner coolant flow tubes extending in a longitudinal direction for carrying coolant flow from a heat source for transferring heat from the coolant fluid to ambient water, the inner coolant flow tubes being generally rectangular in cross section, and disposed in a generally parallel relationship, the inner coolant flow tubes having at least one set of open ends in proximity to each other, said header comprising:

an inlet end portion receiving from and/or delivering coolant to the open ends of the inner coolant flow tubes; and

a closed end portion opposite said inlet end portion, said closed end portion being transverse to the longitudinal direction toward the inner coolant flow tubes; the closed end portion having a beveled wall beveled from an end plane perpendicular to the longitudinal direction of the inner coolant flow tubes and located at a part of said closed end portion spaced furthest from the set of open ends of the inner coolant flow tubes, in the direction towards the inner coolant flow tubes.

22. A header according to claim 21 wherein said closed end portion includes an end wall extending from and perpendicular to said upper surface of said header, and said beveled portion being beveled from said wall towards the coolant flow tubes.

23. A header according to claim 22 wherein the amount of bevel of said beveled wall is at an exterior angle θ measured from said end plane to said beveled wall,

24. A header according to claim 23 wherein said angle θ is 52°.

25. A header according to claim 23 wherein said header has a flat upper surface perpendicular to said end plane, and said closed end portion includes an end wall extending from said flat upper surface and being in said end plane, and said beveled wall extending from said vertical wall at an exterior angle θ from said end wall, said angle θ being between 0° and 90°.

26. A header according to claim 25 wherein said beveled wall has a length greater than the height of said end wall.

27. A header according to claim 25 wherein the height of said vertical wall is no greater than 1.125 inches.

28. A heat exchanger for cooling or heating a heat transfer fluid, said heat exchanger comprising:

a plurality of parallel, heat transfer fluid flow tubes for carrying heat transfer fluid between a heat source and a heat sink, said flow tubes including inner tubes and exterior side tubes, said inner flow tubes having a set of open ends in proximity to each other; and

a header having a chamber and being connected to said set of open ends

of said inner flow tubes, said header having an inner end portion for receiving said set of open ends of said flow tubes and an outer closed end portion opposite said inner end portion, and a roof section; said inner end portion, said outer end portion and said roof section defining part of said chamber, said outer closed end portion having a beveled portion beveled at an interior angle with respect to said roof section of less than 90°.

29. A heat exchanger according to claim 28 wherein said roof section is generally flat, said outer closed end portion has an end wall generally perpendicular to said roof section, and said beveled portion is beveled from said end wall at an exterior angle of greater than 0° and less than 90°.

30. A heat exchanger according to claim 28 wherein the heat source is a heat generating component of water vessel, the heat sink is the ambient water, and said heat exchanger is a keel cooler, and wherein said heat transfer fluid flow tubes are generally rectangular in cross section.

31. A keel cooler according to claim 30 wherein said roof section is generally flat, said closed end portion has an end wall generally perpendicular to said roof section, and said beveled portion is beveled from said end wall at an exterior angle θ (theta), angle θ being greater than 0° and less than 90°.

32. A keel cooler according to claim 31 wherein said flow tubes have external side height of 2 ½ inches and an external side widths of ½ inch.

33. A keel cooler according to claim 32 wherein said angle θ is 52°.

34. A keel cooler according to claim 31 wherein said beveled portion has a length greater than the height of said end wall.

35. A keel cooler according to claim 28 wherein said roof section is generally flat, and said closed end portion has an end wall transverse to said roof section, and said beveled portion extends from said end wall.

36. A keel cooler according to claim 30 wherein said inner flow tubes are generally straight in length and have a second set of open ends in proximity to each other at the other end of said inner flow tubes, and wherein heat exchanger further comprises:

a second header at the other end of said inner flow tubes, said second header having a chamber and being connected to said set of open ends of said

inner flow tubes, said header having an inner end portion for receiving said set of open ends of said inner flow tubes and an outer closed end wall portion opposite said inner end portion, and a roof section; said inner end portion, said outer end portion and said roof section defining part of said chamber, said outer closed end portion having a beveled portion beveled at an interior angle with respect to said roof section of less than 90°;

one of said header and said second header having an inlet conduit for conducting hot heat transfer fluid from the heat source into said one header, and the other of said header and said second header having an outlet conduit for conducting cooled heat transfer fluid towards the heat source.

37. A keel cooler according to claim 36 wherein said inlet conduit is an inlet nozzle and said outlet conduit is an outlet nozzle.

38. A heat exchanger according to claim 28 wherein said heat transfer flow tubes are generally rectangular in cross section and have external side heights of 2 ½ inches and external side widths of ½ inches.

39. A multiple pass heat exchanger comprising:

two exterior side tubes having orifices near the opposite ends of said exterior side tubes for conducting heat transfer fluid into and out of said exterior side tubes;

at least one interior side tube having an orifice near one end and an open opposite end for conducting heat transfer fluid into or out of said interior side tube; and

first and second opposing headers having chambers, said first header having means for receiving from a heat source, heated heat transfer fluid, each header having:

an inner end portion;

a roof section;

a closed outer end portion opposing said inner end portion, said closed outer end portion having a beveled portion beveled with respect to said roof section downwardly toward said inner end portion, the ends of said exterior side tubes forming part of the chambers of said first and

second headers, said orifices opening into the chambers; and

said interior side tube extending to said closed outer end portion of one of said headers to divide said first header into multiple chambers, said interior side tube preventing the mixing of heat transfer fluid in said multiple chambers.

40. A multiple pass heat exchange according to claim 39 wherein said means for receiving heated heat transfer fluid is in one of said multiple chambers, and further includes means in another of said multiple chambers of said first header for discharging to the heat source cooled heat transfer fluid.

41. A multiple pass heat exchanger according to claim 39 and further including means in said second header for discharging to the heat source cooled heat transfer fluid..

42. A multiple pass heat exchanger comprising:

at least two sets of parallel heat transfer fluid flow tubes extending in a longitudinal direction for conducting heat transfer fluid in opposite directions, each set of flow tubes including:

an exterior side tube having orifices for conducting heat transfer fluid into and out of said exterior side tube;

an interior side tube having open opposite ends for conducting heat transfer fluid into or out of said interior side tube, said interior side tubes being adjacent to each other; and

first and second opposing headers having chambers, each header having;

an inner end portion;

a roof section;

a closed outer end portion opposing said inner end portion, said closed outer end portion having a beveled portion beveled with respect to said roof section downwardly toward said inner end portion, the ends of said exterior side tubes forming part of the chambers of said first and second headers; and

at least one separator plate between said interior side tubes in at least one of said headers for dividing said header(s)

into multiple chambers and preventing the mixing with heat transfer fluid between said multiple chambers.

43. A multiple heat exchanger comprising:

exterior side tubes having orifices near the opposite ends of said exterior side tubes for conducting heat transfer fluid into and out of said exterior side tubes;

a pair of adjacent interior side tubes having orifices near the respective ends facing in opposite directions away from each other, for conducting heat transfer fluid into or out of said interior side tube; and

first and second opposing headers having chambers, said first header having means for receiving heated heat transfer fluid, each header having:

an inner end portion;

a roof section;

a closed outer end portion opposing said inner end portion, said closed outer end portion having a beveled portion beveled with respect to said roof section downwardly toward said inner end portion, the ends of said exterior side tubes forming part of the chambers of said first and second headers, said orifices opening into the chambers; and

said interior side tubes extending to said closed outer end portion of said headers to divide said headers into multiple chambers, said interior side tubes preventing the mixing of heat transfer fluid between the chambers, said means for receiving heated heat transfer fluid entering one of said chambers and said means for discharging heat transfer fluid entering another of said chambers.

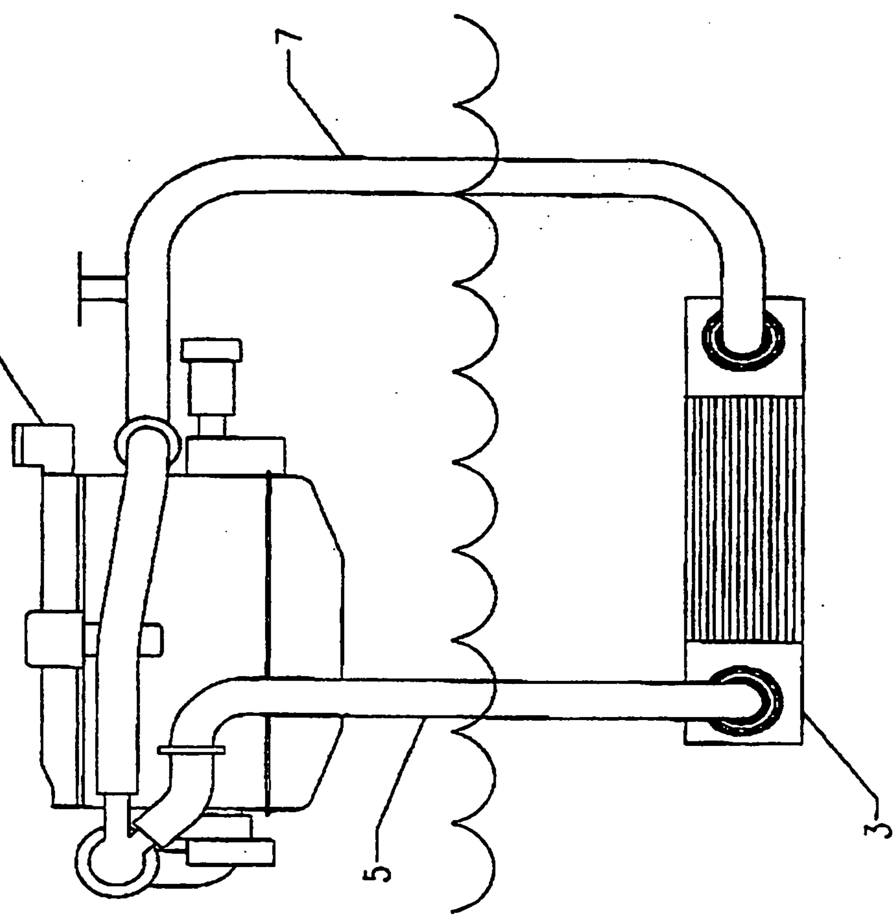


FIG. 1

PRIOR ART

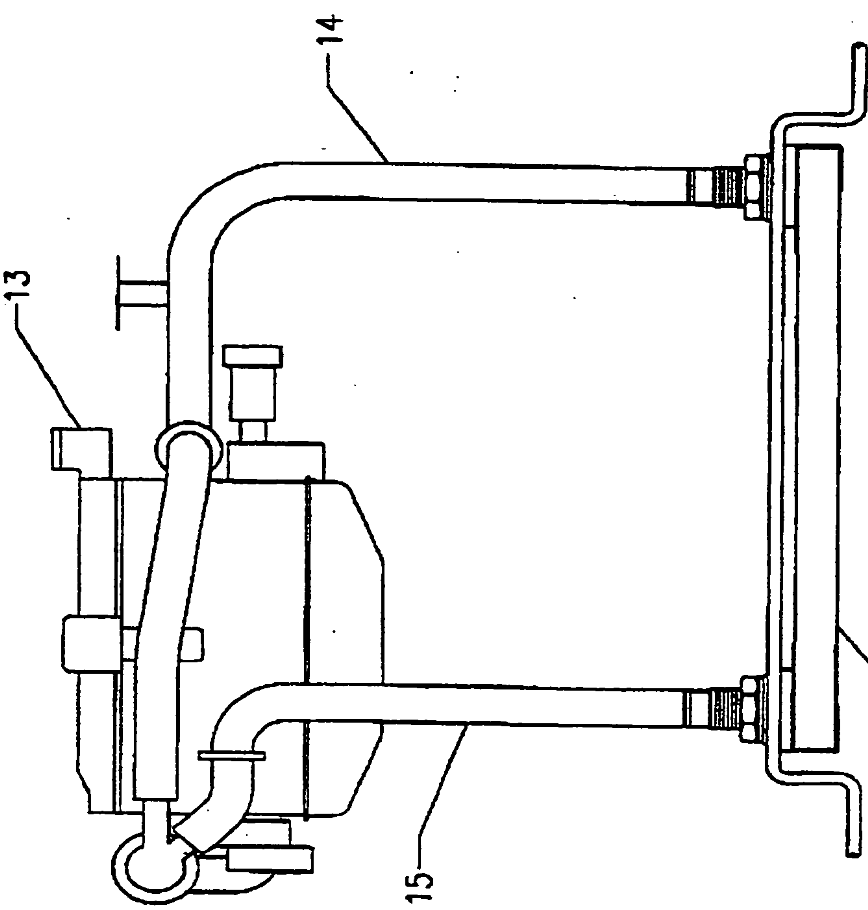
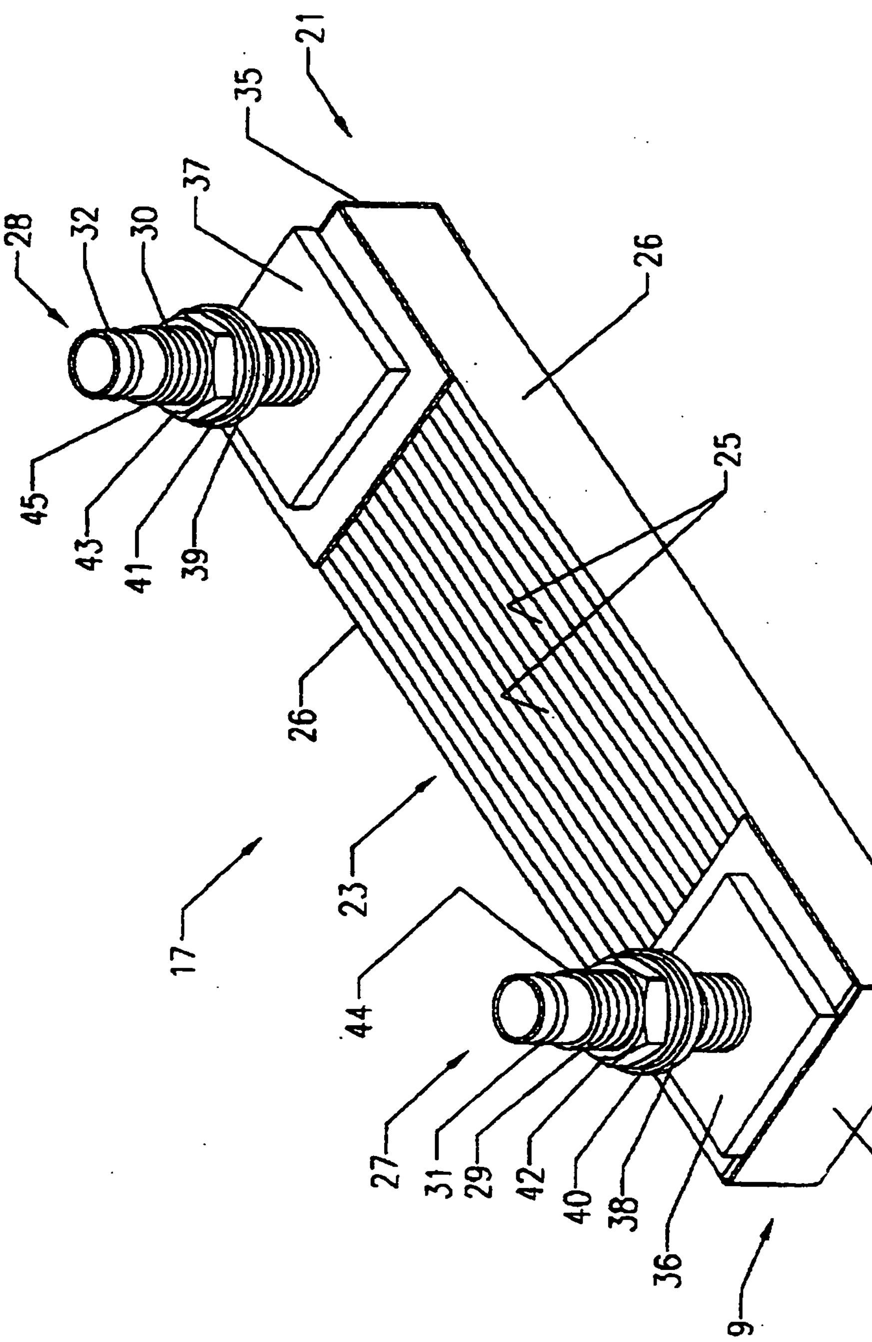


FIG. 2



PRIOR ART

FIG. 3

PRIOR ART

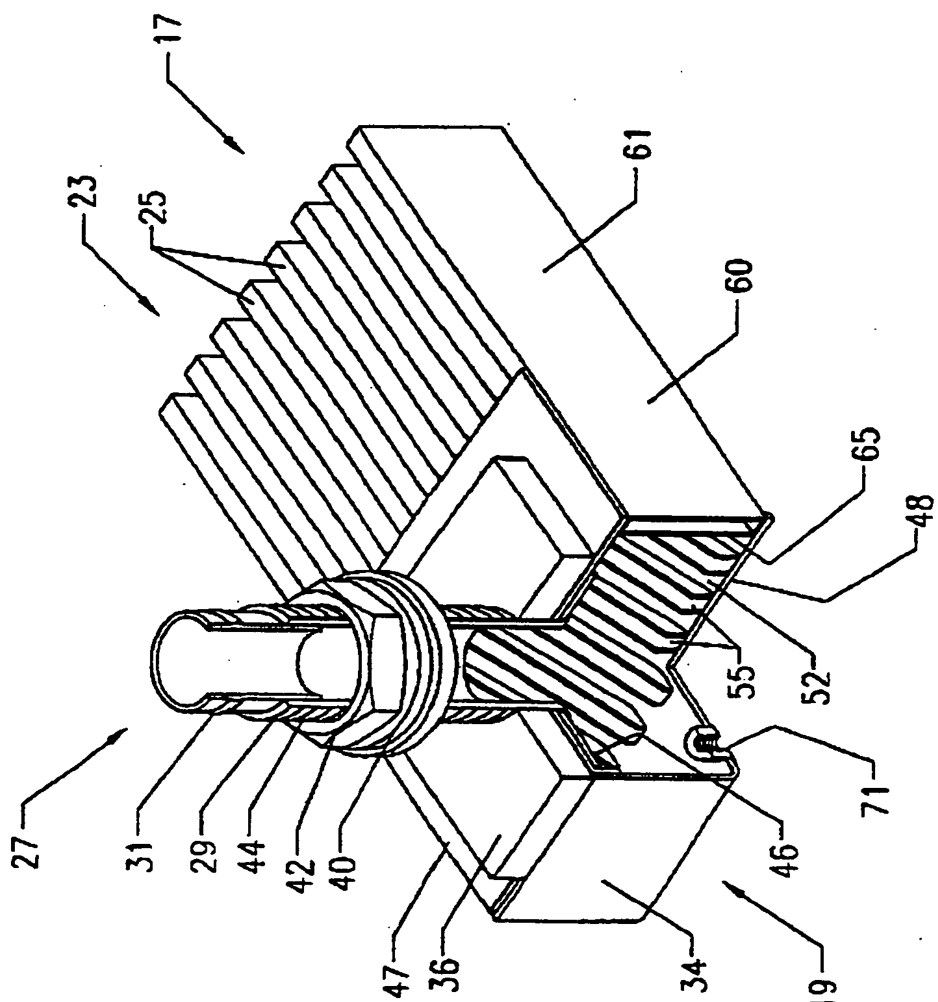


FIG. 4

PRIOR ART

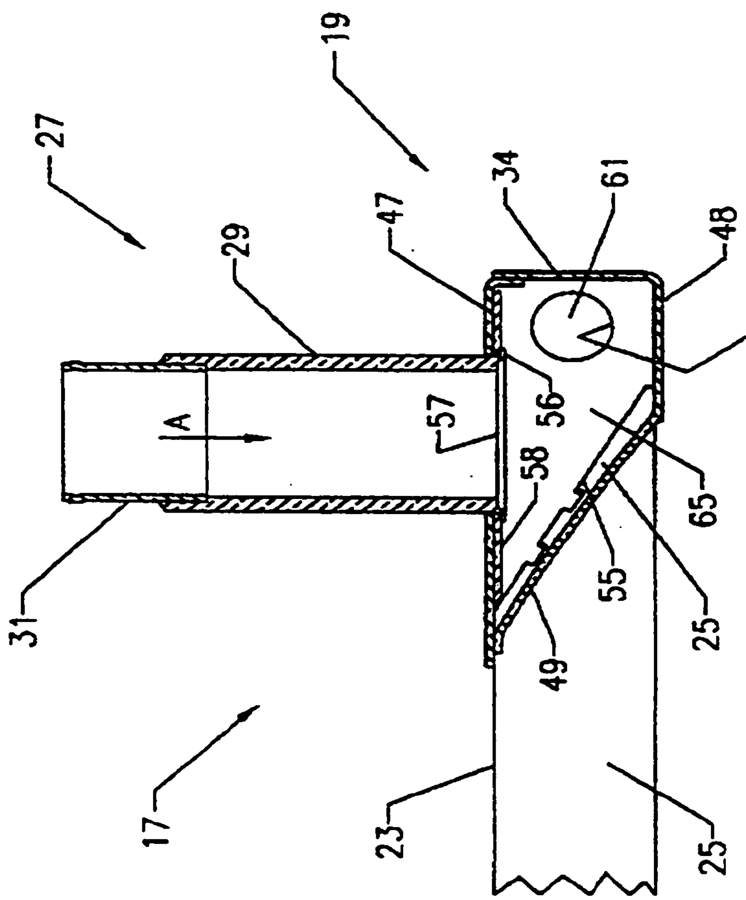


FIG. 5

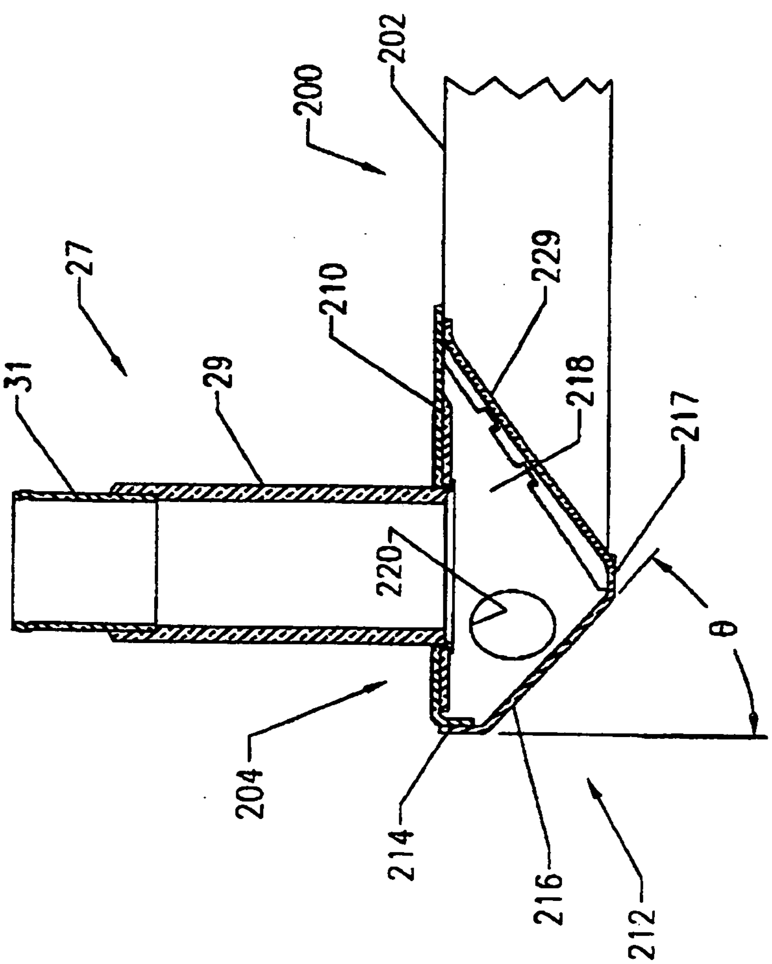


FIG. 6

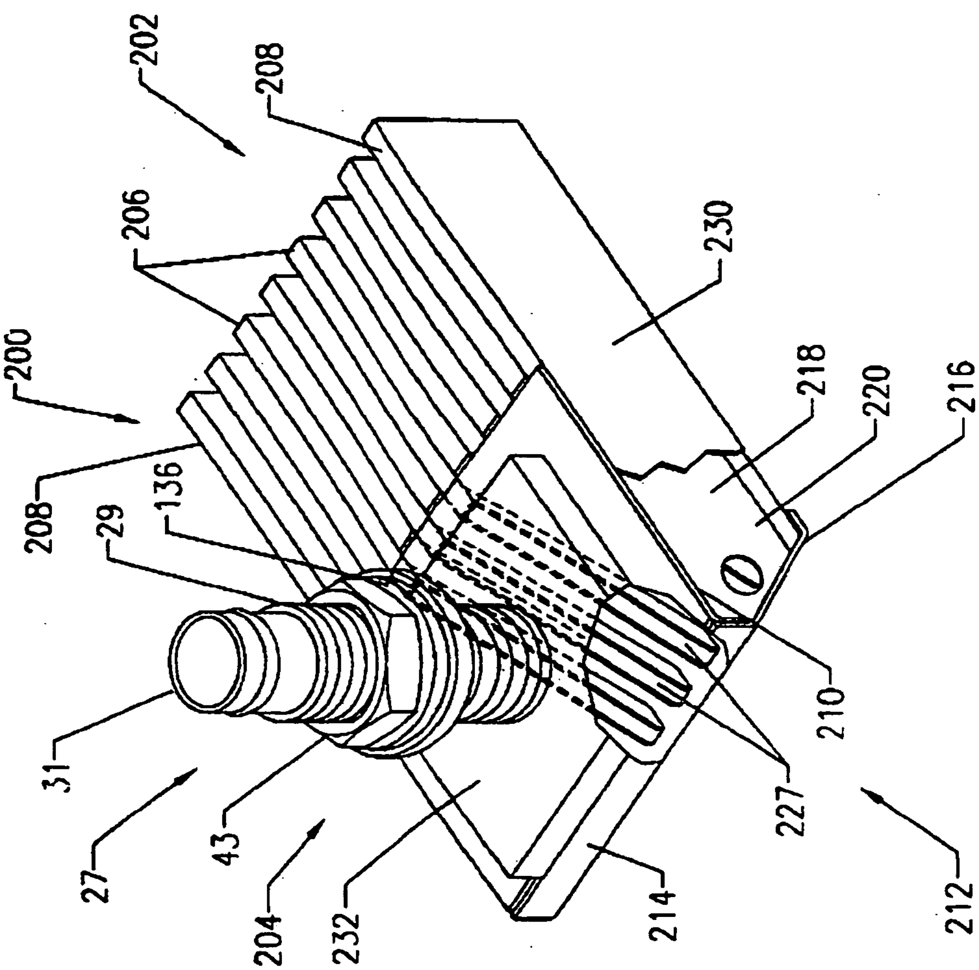

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FIG. 7

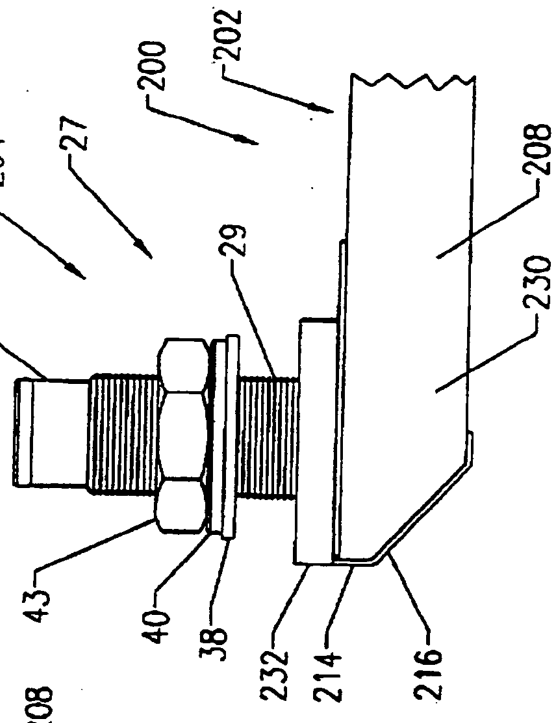
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FIG. 9

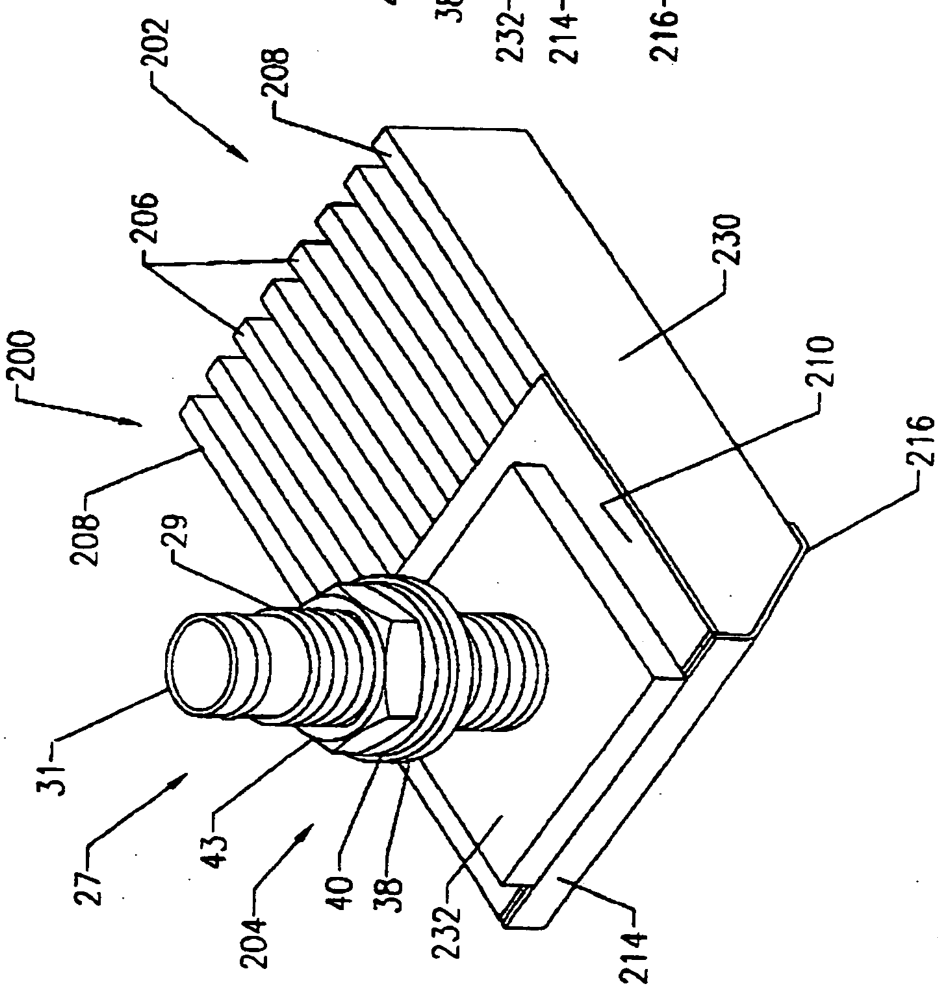
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FIG. 8

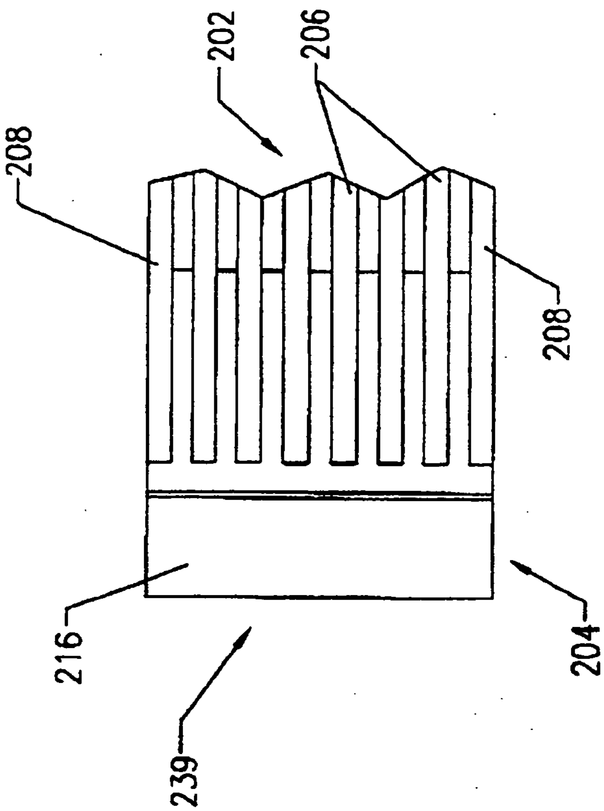

FIG. 11

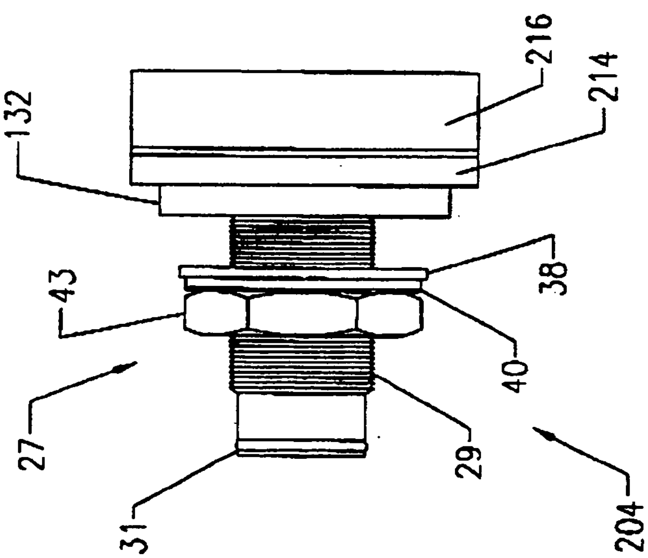

FIG. 10

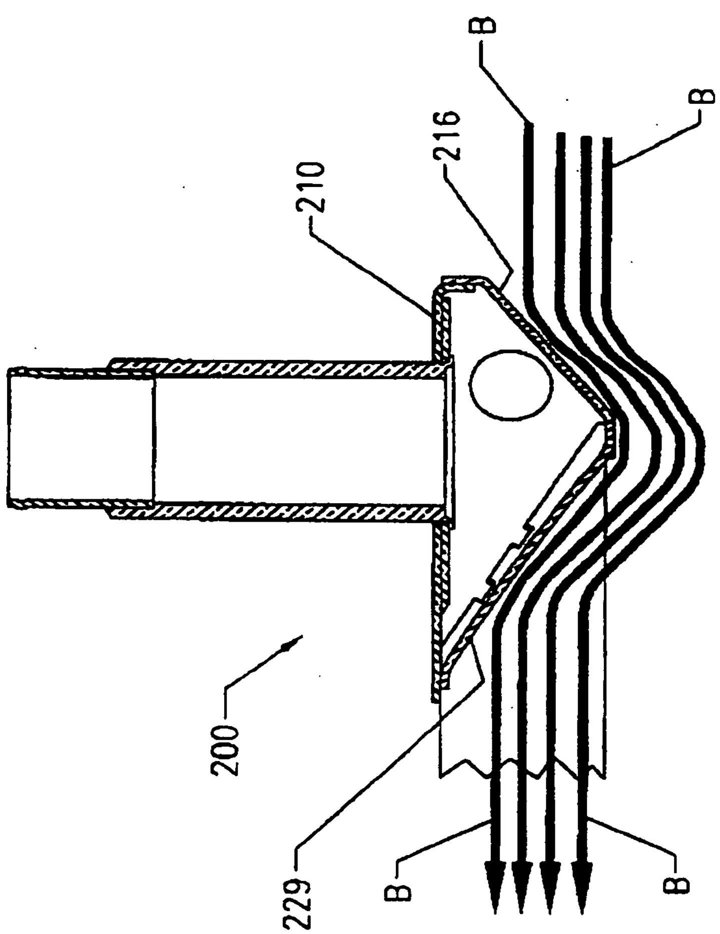

FIG. 12

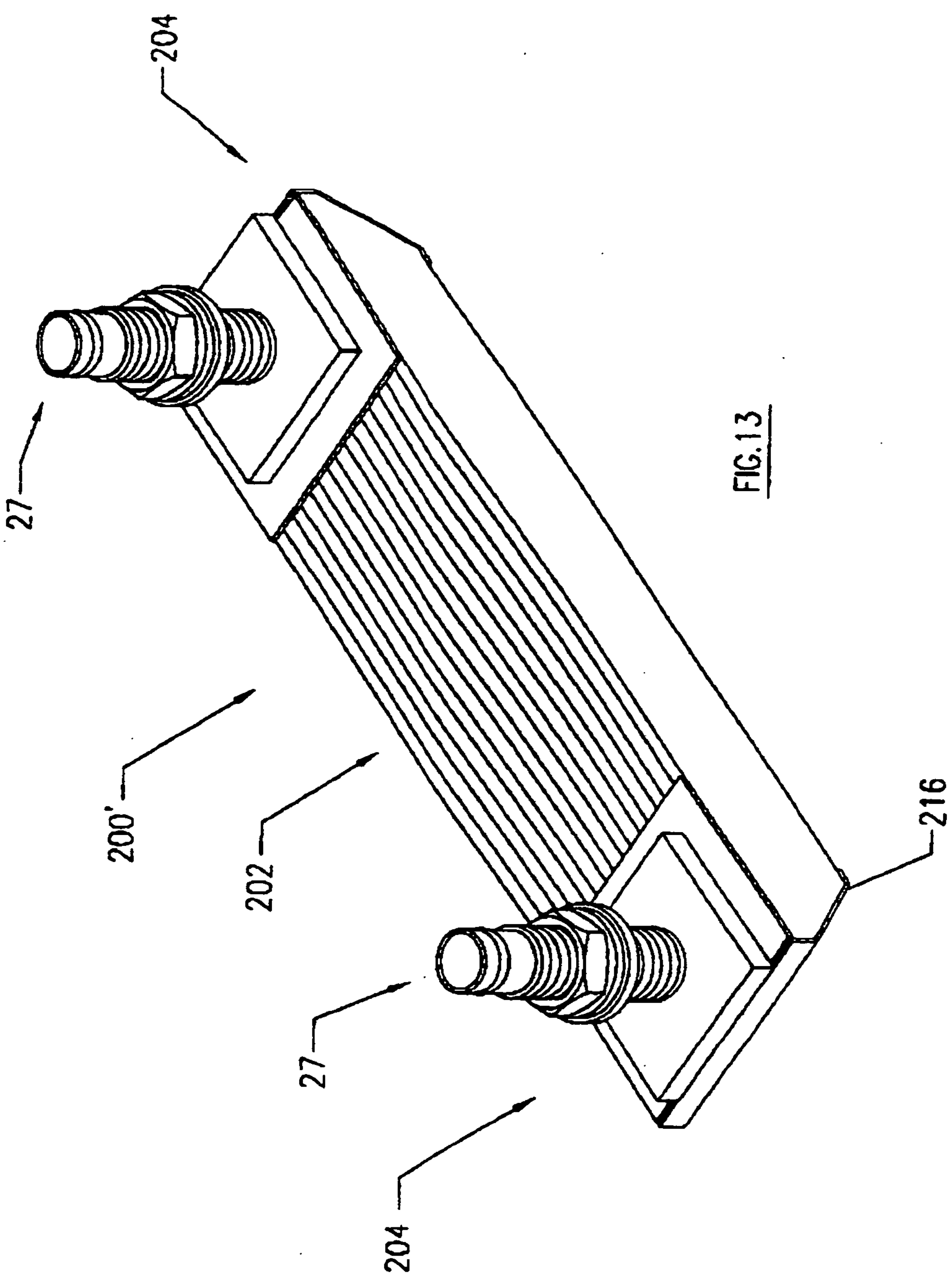

FIG.13

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09/427,565 26 October 1999 (26.10.1999) US

(71) Applicant: DURAMAX MARINE, LLC [US/US]; 15986 Valplast Road, Middlefield, OH 44062-0250 (US).

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(74) Agent: HOCHBERG, D., Peter; D. Peter Hochberg Co., L.P.A., 6th floor, 1940 East 6th Street, Cleveland, OH 44114-2294 (US).

(81) Designated States *(national)*: AU, BR, CA, CN, IN, IS, JP, KR, MX, NZ, PL, SG, TR, ZA.

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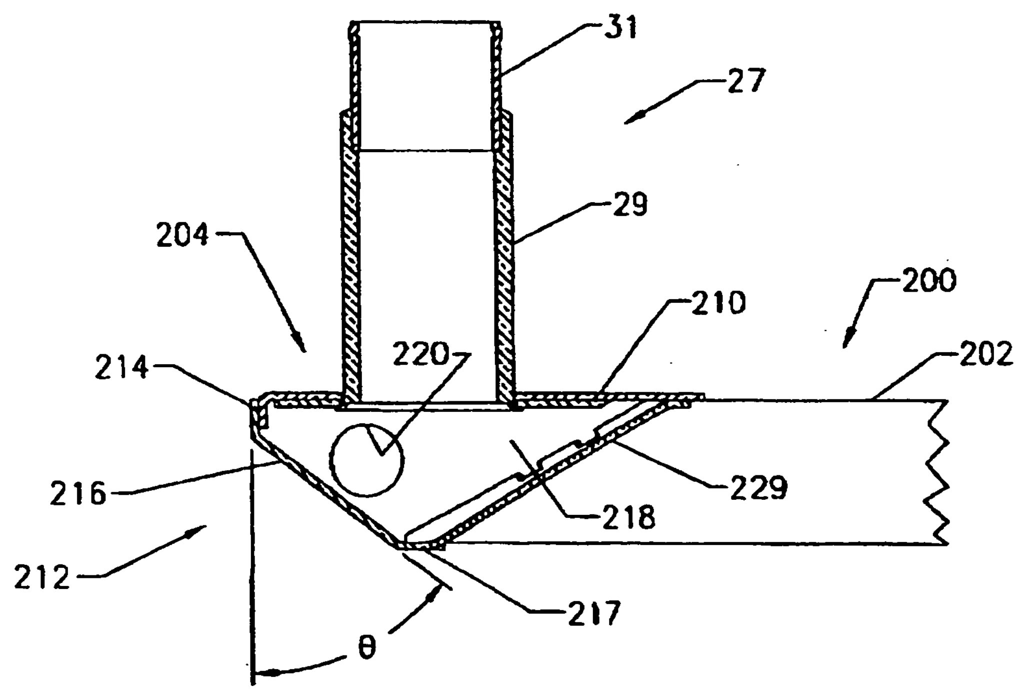
For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: HEAT EXCHANGER WITH BEVELED HEADER



(57) Abstract: A header (204) for a keel cooler heat exchanger (200), the header (204) having a beveled closed end portion (216).

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INTERNATIONAL SEARCH REPORT

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PCT/US00/41599

A. CLASSIFICATION OF SUBJECT MATTER

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US CL :165/44; 440/88
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 165/41,44; 440/88

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
NONE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	U.S. 2,382,218 (FERNSTRUM) 14 August 1945 , see entire document, particularly Figure 5 and header 14a.	1-43
Y	U.S. 2,415,154 (WALTER) 04 February 1947, see entire document, particularly Figures 11-12 and partition 75a.	39-43

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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Date of the actual completion of the international search 10 MAY 2001	Date of mailing of the international search report 22 MAY 2001
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer T. Hurley for JOHN K. FORD Telephone No. (703) 3082636

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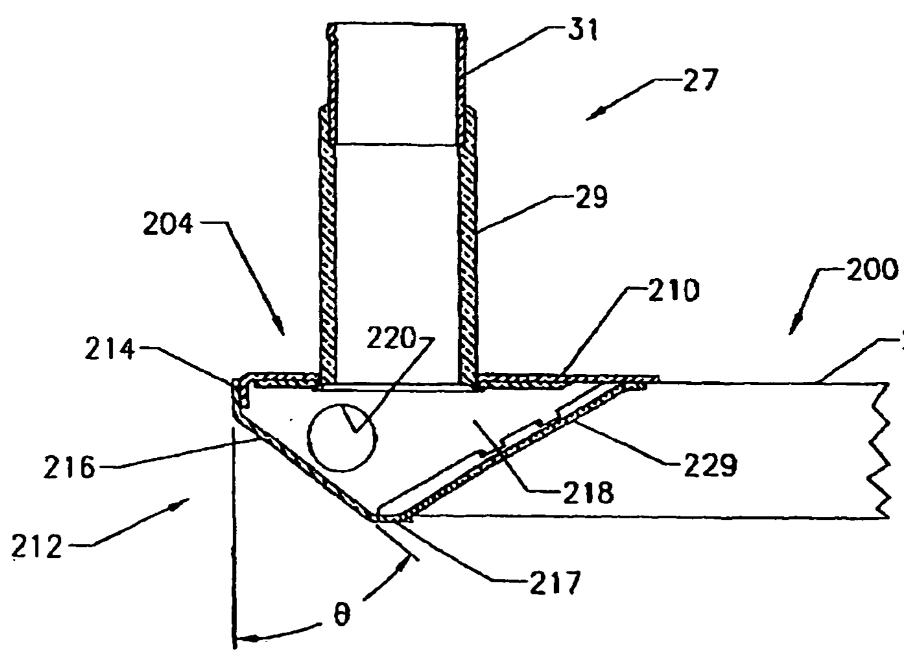
[Continued on next page]

(54) Title: HEAT EXCHANGER WITH BEVELED HEADER



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